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Dental Disease in the Chinese Yin-Shang Period With Respect to Relationships Between Citizens and Slaves

REIKO SAKASHITA,[1]* MASAKAZU INOUE,[1] NAOHIKO INOUE,[2] QIFENG PAN,[3] AND HONG ZHU[4]
[1]*Department of Preventive Dentistry, Kagoshima University Dental School, Kagoshima 890, Japan*
[2]*The University of Tokyo, Bunkyoku, Tokyo 113, Japan*
[3]*Center for Archaeometry, The Institute of Archaeology, Chinese Academy of Social Sciences, Beijing 100710, People's Republic of China*
[4]*Department of Archaeology, Jilin University, Changchun, Jilin Province 130023, People's Republic of China*

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ABSTRACT Seventy-one skulls from the Yin-Shang period tombs of Anyang, China, were examined for the incidence of observable dental diseases, including dental caries, alveolar bone resorption (an index of periodontal disease), ante-mortem tooth loss and tooth attrition. Because the remains were excavated from tombs with funerary items, the burials are believed to be of Anyang citizens. Our study indicates carious tooth frequency in the Yin-Shang period was rather low (2.9–4.0%). Periodontal disease frequency was 18.3–26.9%, and ante-mortem tooth loss frequency was 2.0–7.5%.

To determine the relative prevalence of overall dental health in the Yin-Shang populations, observations from the 42 male crania were compared to those from 183 male crania of slaves from "sacrificial pits" from the Yin-Shang period (Inoue et al. [1992] J. Anthropol. Soc. Nippon *100:*1–29). Results from this comparison indicate no apparent difference between social classes in younger age groups. However, in the older ages the rates of the ante-mortem tooth loss, periodontal disease and tooth attrition were significantly higher in the citizen sample. The findings would suggest dietary development in the Yin-Shang period was not dissimilar enough between social classes to induce clear differences in dental diseases at least at younger ages. Conversely, it appears there must have been significant differences between social class diets in the earlier phase of the Yin-Shang period to produce the differences in dental disease present in the older samples. Am J Phys Anthropol 103:401–408, 1997.

Attributes in dental health and prevalence of disease can provide an osteo-archaeological record indicative of the level of dietary and cultural sophistication for prehistoric and modern populations. Many previous studies have discussed how changing patterns of dental diseases are related to cultural and dietary change. Studies on Native American (Hodges, 1987; Larsen, 1984), British (Moore and Corbett, 1973, 1975, 1976), South Asian (Lukacs, 1992), East Asian (Turner, 1979) and Japanese (Inoue, 1981a, 1981b) populations indicate that marked increase in dental caries in populations is related to economic progress. Not only dental caries but also ante-mortem tooth loss (AMTL), alveolar resorption and

Current address for Dr. Inoue is 1-32-3 Fuda, Chofu, Tokyo 182, Japan.

*Correspondence to: Reiko Sakashita, Department of Preventive Dentistry, Kagoshima University Dental School, 8-35-1 Sakuragaoka, Kagoshima 890, Japan. E-mail: reiko@dentlb.hal.kagoshima-u.ac.jp

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enamel hypoplasia increase as subsistence becomes more intensive and as food preparation and storage technology become more efficient (Lukacs, 1992; Hillson, 1979). Among people living at the same time, differences in dental diseases are often accompanied by diet difference in relation to sex, social status and cultural background (Hill and Hurtado, 1989; Walker and Hewlett, 1990; Bedi et al., 1991). Thus the degree and extent of dental disease can describe the level of oral health and indicate the types of diet by effects of foodstuffs on the dentition as well as on growth and development. These factors in conjunction with the archeological record can elicit interpretations into the extent of cultural development and the overall quality of life of individuals living during a particular time.

Historical and archaeological evidence has certified that the Shang dynasty is the oldest dynasty of China (Li, 1985). The dynasty is also known as the first monarchical slave state in Chinese history (Yang, 1986). Although archaeological findings indicate that Shang subsistence relied on agriculture (Li, 1985; Yang, 1986), some investigators have suggested that hunting was still common, and the Shang agricultural system was not highly developed (Ching, 1990). The intent of this paper is to interpret the level of dental health and dietary variation in the Yin-Shang period of the Shang dynasty by examining the remains of citizens and slaves for various attributes of dental disease. From the results, differences in the dietary background between social classes in ancient China will be proposed.

MATERIALS AND METHODS

Citizen sample

A collection of skulls from the Yin-Shang period, the so-called Da-si-kong series, was studied. It was excavated from small or middle-sized tombs at Anyang, China. The tombs contained complete burials with some funerary objects and cultural ornaments, suggesting that the dead interred were citizens of the city. Of the 150 sets of remains, 42 male and 29 female adult crania were selected for study based on the quality of their preservation. Morphological sex and age had been previously determined by staff of the Institute of History and Institute of Archaeology, based on features of the pelves, long bones and crania (Institute of History and Institute of Archaeology, CASS, 1985). The remains are curated in the Institute of History and Institute of Archaeology, CASS, People's Republic of China.

From translated inscriptions found on "Jiaguwen" (an inscribed writing on bone and tortoise carapace), it has been determined that Anyang flourished as the capital city during the latter half of the Yin-Shang period. Its history encompasses approximately 300 years, from 1400 to 1100 B.C., when King P'an Keng moved to Anyang at the end of the Shang dynasty (Li, 1985). The Shang dynasty, as a Bronze Age culture, manifested an extensive metalworking industry. Despotism effectively controlled large centralized government centers and urban communities, requiring a multitude of agricultural communes to support these centers and the industrial workers (Yang, 1986). Therefore, there was considerable use of slaves in the agricultural and industrial workforce.

Archaeological investigations indicate the cultivation of millet, wheat and rice, with millet being the primary food source (Li, 1977; Yang, 1986). Domesticated livestock such as pigs, cows, sheep and goats were the principal meat protein sources, but remains of wild animals are also found in the archeological record (Ching, 1990). Numerous elaborate forms of specific bronze vessel types indicate that liquor production occurred, using millet as the most likely grain.

Slave sample

The authors have previously reported their investigation of the Xi-bei-gang series of skulls from the Yin-Shang period of China (Inoue et al., 1992). These skulls were excavated from what are considered to be "sacrificial pits" surrounding several royal tombs at Houchiacung, Anyang, China. The pits contained approximately 10 cut crania each, apparently decapitations, since no postcranial remains and no associated cultural remains were found. In addition to this, several skulls displayed signs of trauma on the upper jaw, which indicate that they had

TABLE 1. Age distribution of materials

	Age group composition (%)[1]					Total number of skulls
	<17	17–24	25–44	45–59	>60	
Citizens						
Male	0.0	28.6	40.5	31.0	0.0	42
Female	6.9	24.1	44.8	24.1	0.0	29
Slaves						
Male	2.7	36.1	47.0	13.1	1.1	183

[1] Age in years.

TABLE 2. Criteria for dental examination

Caries tooth
- 0 Sound teeth.
- 1 Caries cavity on either occlusal fissure or smooth surface of the tooth, of which extent is limited within the enamel layer. A coloration of occlusal fissure without any evidence of decalcification or softening of the enamel to which an explorer could not be pushed in was excluded.
- 2 Caries cavity reaches into dentine, but not to the dental pulp. Normally, the apex of explorer is buried to 2 mm into a cavity.
- 3 Caries cavity reaches to the dental pulp. Approximately one-fifth of tooth crown was destroyed.
- 4 Tooth crown is almost destroyed and only root remains.

Periodontally involved tooth
- 0 No resorption of alveolar bone crest.
- 1 Slight resorption confined to alveolar crest.
- 2 Early, notch-like resorption of the alveolar crest.
- 3 Moderate horizontal loss of alveolar crest that is limited within half of the length of tooth root.
- 4 Advanced bone loss that reaches to more than half of the length of tooth root; and/or a infrabony pocket is formed.

Dental attrition
- 0 Not evident.
- 1 Limited to enamel
- 2 Reaches to dentine.
- 3 Reaches to dental pulp.

been cut off with a scythe. The skulls are believed to be from slaves, sacrificed for the consecration of royal tombs (Institute of History and Institute of Archaeology, CASS, 1985).

Because there were few female skulls in this collection, we focussed on male skulls, and used 183 of them to evaluate possible differences in dental health between slaves and citizen males of the present study. Data for the slave population were obtained from our previous study (Inoue et al., 1992). The slave remains are part of the collections of the Institute of History and Philology, Academia Sinica, Taiwan.

The two samples are considered to be from essentially contemporaneous populations (within 100 years), existing around 1400 to 1300 B.C. (Yang, 1986). The sample sets used in this study are summarized in Table 1.

Examination of dental diseases and indices

Dental caries. The dentition was examined by visual inspection, often using a dental explorer to determine the integrity of the enamel surface for the existence of detectable defects. Defects were scored as 0, 1, 2, 3, or 4 (Table 2) according to the standards set for investigation of skeletal materials (Inoue et al., 1982) based on routine criteria used in Japan for clinical dental caries determination (Shimada, 1968). Scores 1 to 4 were defined as "carious teeth."

Periodontal disease. To determine the extent of periodontal disease, marginal alveolar bone resorption was scored for each tooth as 0, 1, 2, 3 or 4 (Table 2). These criteria are modifications of the Russell's Periodontal Index (Russell, 1956) designed for skeletal materials (Inoue et al., 1982). Scores 3 and 4 were defined as "periodontal disease positive."

Ante-mortem tooth loss (AMTL). In order to determine whether tooth loss had occurred ante-mortem, the alveolus where the tooth was lost was examined. To be identified as ante-mortem loss of the tooth, the edentulous area must exhibit 1) shallowing of the socket, 2) a dull alveolar margin and 3) some aspects of the cortical bone covering.

Morbid tooth. Any tooth which was carious, periodontally involved and/or antemortemly lost was defined as a "morbid tooth."

Indices of dental diseases. 1) Carious tooth rate was calculated as the number of involved teeth respective to the number of present teeth; 2) periodontally involved tooth rate was calculated as the number of involved teeth respective to the number of present teeth; 3) AMTL rate was calculated as the number of teeth involved per the number of examined teeth (present teeth plus AMTL); 4) morbid tooth rate was calcu-

lated as the number of teeth involved per the number of examined teeth; 5) DMT (decayed and missing teeth) rate was calibrated as the number of carious teeth plus AMTL per the number of examined teeth; 6) morbid tooth rate was calculated as the number of morbid teeth over the number of examined teeth.

Dental attrition. Wearing of tooth enamel (and dentine) was evaluated at the most extreme tooth in each skull and scored using the arbitrary scale ranging from 0 to 3 (Table 2) (Inoue et al., 1982).

Comparative analyses

As was stated above, few female crania exist in the slave sample, so to provide the most accurate comparison between the citizen and slave samples, only males were used in the analysis (Table 1). Additionally, the citizen sample contains higher proportions of older ages than found in the slave sample (χ^2; $P < 0.05$). Therefore, differences between the citizen and slave samples were analyzed by age groups: I (17–24 years old), II (25–44 years old) and III (45–59 years old).

Comparative data derived from carious teeth, periodontally involved teeth, AMTL, DMT indices and those teeth at risk were evaluated for significance by the Fisher's direct test. The scores of dental attrition were analyzed by the Wilcoxon's rank sum test.

RESULTS

The various frequencies for dental disease rates and indices are presented in Table 3. The rates of dental diseases for each age group of male citizens and slaves are summarized in Table 4. The numbers of teeth involved increased in the higher age groups. No significant difference of carious tooth rate was found between citizens and slaves in any age group. However, the periodontally involved tooth rate appeared to be a little higher for slaves than for citizens in age group I (17–24 years old). Conversely, the periodontal involved tooth rate was significantly higher for citizens than for slaves in age group II (25–44 years old). AMTL rate and DMT rate were also significantly higher for citizens than for slaves in age group III (45–59 years old). Consequently, the rate of morbid teeth was higher in age groups II and III for citizens than for slaves.

TABLE 3. Prevalence of dental diseases

	Male %	Female %	Total %
Carious tooth rate			
Citizens	3.7 (25/684)	4.5 (19/419)	4.0 (44/1103)
Slaves	2.9 (103/3547)		
Periodontal involvement			
Citizens	27.0 (183/679)	26.9 (113/420)	26.9 (296/1099)
Slaves	18.3 (615/3346)		
AMTL rate			
Citizens	9.4 (71/755)	4.3 (19/438)	7.5 (90/1193)
Slaves	2.0 (73/3620)		
DMT rate			
Citizens	12.7 (96/755)	8.7 (38/438)	11.2 (134/1193)
Slaves	4.9 (176/3620)		
Morbid tooth rate			
Citizens	34.4 (262/762)	32.3 (144/446)	33.6 (406/1208)
Slaves	23.1 (777/3364)		

The tooth to tooth distribution of dental caries, periodontal disease and AMTL showed similar patterns for both social classes in all age groups: 78.4% (98/125) of caries, 66.3% (519/783) of periodontal disease and 72.6% (98/135) of AMTL occurred at molars.

Tooth attrition was more extreme for citizens than for slaves in all the age groups (see Table 5).

DISCUSSION

Evaluation of dental diseases

It has been debated (Klein et al., 1938; Whittaker et al., 1981; Lukacs, 1995) whether carious tooth rate estimates generated from teeth remaining in situ would produce an underestimate of decay because a considerable portion of the AMTL frequency is attributed to severe tooth decay. Kelley et al. (1991) have assumed that most AMTL is produced by tooth decay and they advocate the use of a DMT (decayed and missing teeth) index. Very recently, Lukacs (1995) has established a "caries correction factor" for calibrating carious tooth rate to

TABLE 4. Prevalence of dental diseases by age group

	17–24 years old (%)			25–44 years old (%)			45–59 years old (%)		
	Max.	Mand.	Total	Max.	Mand.	Total	Max.	Mand.	Total
Carious tooth rate									
Citizens	0.0	1.2	0.5	4.5	2.8	3.7	1.0	11.1	6.4
	(100)	(85)	(185)	(154)	(145)	(299)	(96)	(108)	(204)
Slaves	0.9	2.1	1.4	2.4	4.7	3.3	5.2	7.6	6.1
	(832)	(476)	(1308)	(1062)	(621)	(1683)	(291)	(171)	(462)
Periodontal involvement									
Citizens	4.1*	7.1	5.5*	33.8**	31.5***	32.7***	39.8	34.9	37.1
	(98)	(85)	(183)	(151)	(143)	(294)	(93)	(109)	(202)
Slaves	11.2	11.4	11.3	23.1	14.0	19.9	30.4	36.2	32.7
	(786)	(457)	(1243)	(998)	(551)	(1549)	(286)	(185)	(471)
AMTL rate									
Citizens	1.0	0.0	0.5	0.6	4.6	2.6	26.7***	20.0**	23.3***
	(101)	(85)	(186)	(155)	(152)	(307)	(131)	(135)	(266)
Slaves	0.6	1.7	1.0	1.1	1.9	1.4	3.9	8.1	5.7
	(837)	(484)	(1321)	(1074)	(633)	(1707)	(304)	(186)	(490)
DMT rate									
Citizens	1.0	1.2	1.1	5.2	7.2	6.2	27.5***	28.9**	28.2***
	(101)	(85)	(186)	(155)	(152)	(307)	(131)	(135)	(266)
Slaves	1.6	3.7	2.4	3.5	6.5	4.6	8.8	15.1	11.2
	(837)	(484)	(1321)	(1074)	(633)	(1707)	(304)	(186)	(490)
Morbid tooth rate									
Citizens	3.9*	7.1	5.9*	34.2**	35.5**	34.9***	55.0***	53.3	54.1***
	(102)	(85)	(187)	(155)	(152)	(307)	(131)	(137)	(268)
Slaves	11.4	13.7	12.2	24.1	16.9	21.5	35.1	44.6	38.8
	(844)	(488)	(1332)	(1082)	(638)	(1720)	(308)	(202)	(510)

Significant differences between citizens and slaves: * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$. The total number of teeth from which the rate was calculated is shown in parentheses.

TABLE 5. The prevalence of tooth attrition

	17–24 years old		25–44 years old		45–59 years old	
	Citizens (n = 11)	Slaves (n = 63)	Citizens (n = 16)	Slaves (n = 85)	Citizens (n = 13)	Slaves (n = 23)
Occlusal surface (%)						
Score						
0	0.0	7.9	0.0	1.2	0.0	0.0
1	0.0	23.8	0.0	20.0	7.7	13.0
2	100.0	66.7	15.3	71.8	38.5	52.2
3	0.0	1.6	45.5	7.1	53.9	34.8
	*		**			
Proximal surface (%)						
Score						
0	18.2	19.1	0.0	15.3	0.0	8.7
1	81.8	79.4	75.0	83.5	53.9	91.3
2	0.0	1.6	18.8	1.2	46.2	0.0
3	0.0	0.0	6.3	0.0	0.0	0.0
			***		***	

n = number of skulls.
Significant at * $P < 0.05$, ** $P < 0.01$, and *** $P < 0.001$ by the Wilcoxon's rank sum test.

compensate for ante-mortem loss of teeth in skeletal materials. He calculates this correction factor as the frequency of the number of pulp exposures due to caries by the overall loss from pulp exposure due to caries, plus severe attrition. He estimates the AMTL rate due to caries by multiplying the number of AMTL by the rate of teeth with pulp exposure due to caries. Unfortunately, this factor could not be adopted in our study since pulp exposure due to attrition for each tooth was not recorded. Our supplementary record of observations indicates that most teeth with heavy enough attrition to reach the pulp chamber were covered by secondary dentine which helped to prevent pulp exposure. Therefore, most AMTL might be presumed to be caused by caries and the

carious tooth rate corrected by Lukacs' factor would essentially duplicate the DMT ratio.

It should be noted, however, that antemortem tooth loss can also be induced by other causes, such as severe periodontal disease, tooth fracture, traumatic injury and ritual ablation. In our study, periodontal disease was a notable factor for tooth loss in the Yin-Shang materials: 15 of 679 present teeth for male citizens and five out of 3,346 present teeth for male slaves involved terminal periodontal disease. Conversely, pulp exposure due to caries was found in only six teeth in male citizens and in 30 teeth in the slaves. Many epidemiological studies of living people have shown that periodontal disease is a major cause of tooth loss after 35 years of age (Odusanya, 1987; Hatton et al., 1989; Stephens et al., 1991). Thus, both dental caries and periodontal disease (so-called "plaque diseases") are major causes of tooth loss even in ancient populations. Because of this, computing a morbid tooth index, which includes dental caries, periodontal disease and AMTL, was necessary for accurate interpretation of dental disease in the population studied.

Dental disease prevalence and dietary background in Yin-Shang period

Much research has shown that there is a marked increase in dental caries in populations during the transition from a hunting-gathering economy to an agrarian lifestyle. For example, during the Jomon period, the carious tooth rate for hunting and gathering and mixed societies was 9.5%, while the frequency was 19.8% in the agricultural economies in Yayoi, Japan (Inoue, 1981a, 1981b). Lukacs (1992) has reported that the carious rate was 1.2% for Mesolithic hunter-gatherers, 1.4–6.8% in Bronze Age peoples, and 4.4–7.7% in populations experiencing the mixed economy of the Iron Age. Turner's (1979) summary of the carious tooth rate is 0–5.3% (average 1.3%) in hunting-gathering economies, 0.44–10.3% (average 4.8%) in mixed economies, and 2.1–26.9% (average 8.6%) in agricultural economies. Even in living populations, such as contemporary hunter-gatherers like African Pygmies, a lower carious tooth rate (5.2%) occurs than among their neighbor horticulturists (8.1%) (Walker and Hewlett, 1990). In Kenya, pastoralists have fewer carious teeth (6.6%) than do farmers (14.0%) (Ohashi et al., 1994).

Furthermore, periodontal disease and calculus accumulation also show similar patterns. These dental plaque-related diseases are known to occur less frequently in the predynastic period than in the later cemeteries in Egypt (Hillson, 1979). It has also been reported that the prevalence of dental diseases, i.e., tooth decay, enamel hypoplasia, alveolar resorption, AMTL, abscesses and pulp exposure, increased with increasing dependence on agricultural subsistence from the Mesolithic hunter-gatherers of the Ganga Plains, ca. 8000 B.C. to the mixed economy on the Deccan Plateau in the Iron Age (Lukacs, 1992). Similar tendency for periodontitis was observed with contemporary pastoralists and farmers in Kenya (Tatsuki, 1995).

Taken together, the level of dental health is exacerbated with increasing dependence on agriculture which was sustained by a continuing improvement of food productivity and storage technology (Lukacs, 1992). Dental deterioration would be closely related to increased bacterial contamination in the mouth. This would correlate with increased consumption of processed and heated starchy carbohydrates, which constitute a change from the proteinic and fibrous foods from indigenous sources. By analogy, the lower rates of dental caries and periodontal disease in the Yin-Shang period (Table 4) are less than that seen in other agricultural economies in Eastern Asia (Turner, 1979), and suggest that the Yin-Shang diet depended upon undomesticated fibrous foods and meats. Agriculture appears not to have been so highly intensified as to induce a high prevalence of dental caries.

Dietary difference between citizens and slaves

No significant differences in carious teeth and AMTL were found between citizens and slaves in younger ages (Table 4). These findings suggest that the foodstuffs they ingested were apparently not different between the social classes. If there were any

distinct differences in their foodstuffs, especially those which contain refined carbohydrates and sucrose, the effect would have most likely emerged during the early stages of life. It is well known that the period within the first 2 to 4 years after eruption is the period in which teeth are most sensitive to decay (Carlos and Gittelsohn, 1965). Furthermore, the frequency of various dental diseases are closely related to different dietary styles for children and young adults (Harris, 1963; Renson, 1985). Thus, the intensification of agriculture during the Yin-Shang period may have occurred late enough not to have significantly affected the citizens in the present sample through an increase in cariogenic foodstuffs. It is also possible that agricultural production was proficient enough by this time that both social classes were receiving equivalent levels of cariogenic foods in their diet.

In contrast, the rates of periodontal disease, AMTL, DMT, and thereby morbid teeth were significantly higher in citizens than in slaves for the older ages (Table 4). This would suggest higher levels of bacterial contamination in citizens than in slaves. It can be postulated that citizens had access to greater amounts and better processed foods and with more regularity than slaves. This can be supported by the increased tooth attrition observed in the citizen sample (Table 5). Therefore, citizens were exposed to more cariogenic resources which would subsequently predispose them to certain dental afflictions to a greater degree than the slaves were disposed. This disparity in diet, experienced gradually and over a long period, would result in the distinguishable dental deterioration differences observed between the citizen and slave populations.

CONCLUSION

Carious tooth rates were relatively low in the Yin-shang period when compared to other agricultural economies of Asia during that time period. Within the present samples, there appeared to be no difference in the occurrence of dental diseases in citizens or slaves in the younger age categories. This suggests that the level of agricultural subsistence might not have been well enough established to supply the citizens with well processed or cariogenic foodstuffs, or that agricultural subsistence may have progressed to the point where both social classes were equally exposed to cariogenic foods. In the older ages, however, the extent of antemortem tooth loss, alveolar bone loss and tooth attrition was more extreme in the citizen population. These findings suggest citizens were more predisposed to certain dental afflictions. Small differences in their diet, such as cariogenic sugars and carbohydrates, which have effects over a long period, may have produced different levels of dental deterioration. The disparity observed between the citizen and slave samples in this study is most probably due to greater availability to and abundance of foods for the citizens.

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